Goals and safety in chemical industry

As, S. van

Goals and Safety in Chemical Industry

Sicco van As

SOM-theme A Primary processes within firms

Abstract

This paper deals with safety from an organizational perspective. Accidents are actually caused by individual mistakes. However the underlying causes of accidents are often organizational. As a link between these two levels - the organizational failures and mistakes - I suggest the concept of role distance, which emphasizes the organizational characteristics. The general hypothesis is that organizational goals are a main cause of role distance and accident-proneness within organizations. Three different dimensions of 'safety as a goal' are distinguished: priority of safety, and contradictory interests horizontally and vertically. The analysis at different levels does not falsify our hypothesis, and these three dimensions seem to be of interest for the safety in chemical industry.

1 Introduction: accident-proneness

Many industrial disasters in recent years show that organizations and their influence on society have changed dramatically. Most literature dealing with occupational safety emphasizes unsafe working conditions or individual characteristics. The research to be presented below relates to organizational characteristics as a cause of accident-proneness in different industrial organizations. Here the concept of organization relates to human activities performed to produce goods. It implies both the functions and tasks within the production, maintenance and shipping sequences of (chemical) industry. By organization I understand a group of interrelated roles; it comprises formal organization as the product of intended organization design (designed to set collective goals and make arrangements to deploy available resources to attain those goals) and informal organization as a coalition of multiple, possibly conflicting interests characterized by rules not laid down in procedures.

In this paper I will first define the concept of accident-proneness, because "[b]efore anything can be studied scientifically, it must be defined. This step, which sounds so easy, has been a stumbling block for accident research ever since its early days" (Hale and Hale 1972:11, Osborn and Jackson 1988:925). Role distance is introduced as an intermediate variable. I would like to study the influence of priorities and contradictory interests on safety. These different dimensions of 'safety as a goal' are measured and analyzed.

From an organizational perspective risk is about problems of decision-making in the face of uncertainty. Here probability cannot be calculated in a quantitative way but it can only be described in relative terms like 'more' or 'less' (proneness). I adopt a broad definition from everyday English and everyday life, and risk will be defined as: 'human activities that might cause an accident'. The words 'human activities' point to the role of a voluntaristic actor (or: agent) and distinguishes the concept from danger[1]; human action

[1]In literature many different concepts are used, with a slightly different meaning. E.g. danger seems to refer to the possibility that something unpleasant or undesirable might happen without the intervention of an agent, e.g. getting struck by lightning while playing a game of football. The

can reduce or increase the probability (and size) of the damage. This definition fits closely the way in which the concept of risk is used within accident- or safety research. It only involves ‘down-side risk’: problems or accidents, and not the opportunities. Here it equals ‘accident-proneness’ (or: operational risk); which is conceived as the opposite of safety or reliability. This meaning of proneness is different from the one in the human error literature. The human error approach focuses on proneness as differences in personal attributes, e.g. clumsiness (e.g. Hale and Hale 1972:15, Dwyer 1991:56-57) (better: ‘error-proneness’). In this research accident-prone is considered to be an organizational instead of an individual characteristic.

---

related concept of hazard seems to refer to a kind of ‘worst case scenario’, or the potential unpleasant results of technological characteristics (design, construction, material, etc.).

Based on the observation that accidents are actually caused by mistakes (e.g.: Heinrich 1959:13 Leplat 1987:133-, Reason 1990, Adams 1995:16), I will regard mistakes (including dangerous behavior and attitudes[2]) as an aspect of accident-proneness. Of course another aspect are (near-) accidents itself. A near-accident (or 'near miss') is an incident that in other circumstances could have resulted in an accident. A methodological problem is that information about mistakes and near-accidents is highly dependent on beliefs and willingness to report. They are easy to hide, and people are willing to hide because they feel ashamed or afraid to be punished[3] and often they do not consider near-accidents worth reporting. In terms of the famous iceberg metaphor the mistakes are the part under water, the near-accidents are at the surface and the accidents are the part above the water. Because the determinants of accidents and incidents are the same, according to the iceberg-thesis, the consequences are less interesting and the difference is only of academic interest.

The direct observation of the occurrence of accidents is practically impossible since they tend to be rare and unpredictable (Hale and Hale 1972:12). To overcome the reporting artefact somewhat I combined different aspects of accident-proneness and measured them anonymously by a questionnaire instead of relying on the official statistics. The main aspects of accident-proneness are (near-) accidents and mistakes.

2 Role theory

[2]For the use of mistakes, dangerous behaviour, and attitudes as 'alternative criteria for study' see: Hale and Hale 1972:13-4

[3]"For all non-fatal measures of risk there is a[n ..] intractable measurement problem, variously labelled shame, guilt, responsibility, liability, stupidity, or the Hawthorne effect" (J. Adams 1995:90).

As stated, mistakes are the proximate cause of accidents and will even be regarded as an aspect of accident-proneness. However, as we will see, the underlying causes of accidents are organizational. Still the link between individual- and organizational level demands a theoretical description. For this description there are roughly two approaches: (1) the 'Human error approach' that looks at mistakes from out of an epistemological point of view (different kinds of 'irrationality' as a cause of mistakes), and (2) role theory which puts more emphasis on the organizational characteristics.

Because of the dominant role of mistakes in the accident-causation process it is a common approach to study individual limitations (or irrationality) as a source of accidents. Because of its focus at individual limitations this Human error approach is sometimes popularly referred to as 'train and blame ideas'. In a methodological sense (ir)rationality is also a problematic concept to explain human errors. How can I observe the phenomenon? An instrument to measure different kinds of rationality is unknown. In a field study it is very difficult to observe mistakes, but it will be even more difficult to observe different kinds of (ir)rationality. The main problem of an experimental situation is its limited external validity, it is impossible to replicate precisely the conditions that people face in the real world, their historical experience, and other contextual factors.

Role theory[4] and especially the concept of role distance constitute an alternative mediation between the large- and small-scale worlds. Roles serve as the boundary between the organization and the individual, and represent the expectations of both. In the

[4]Role theory can be compared with the more narrow 'adjustment/stress theory' and 'goals/freedom/alertness theory'. The first one postulates that people who are not adjusted to their situation or integrated with it, will be liable to have more accidents. The goals/freedom/alertness theory postulates that people have accidents because they were not alert to their true situation, and that this lack of alertness was the result of a lack of involvement in their work, brought about by being told exactly what to do and what not to do (Kerr in: Hale and Hale 1972:15-6)

work of many authors (e.g. Goffman 1961, Merton and Nisbet 1966, Berger and Luckmann 1966:96, Simon 1997:230) role reveals 'the mediation between the macroscopic universe of meaning objectivated in an organization and the ways in which these universes are subjectively real to individual employees'. The main reason to suggest role to link both levels is the (relatively to the human error approach) strong emphasis on organizational characteristics instead of characteristics of the worker.

Learning one's role in the organization and within the work group, and resolving issues of role distance (role conflict and role ambiguity) has been found critical in individuals' success in organizations. Role conflict and ambiguity are associated with low performance. Many dysfunctional consequences of role conflict and ambiguity in complex organizations are reported: tension, turnover, dissatisfaction, anxiety, a greater concern with own (vs. work group) performance, and lower performance (Gross et al. 1958, Kahn et al. 1964, Rizzo et al. 1970, House et al. 1972, Beehr et al. 1976, Schuler et al. 1977, Schuler 1979). The only dysfunctional consequence not studied yet seems accident-proneness. With few exceptions, research on role distance has investigated or assumed their dysfunctional effects on individual and organizational performance. However, about the relation between role distance and accident-proneness two general hypotheses can be formulated.

Little attention has focused on the possibility that ambiguous or conflicting roles may contribute to organizational performance and may, in fact, be necessary if organizations are to adapt to changes in their environments. This idea, as found in critical and feminist theory (Ritzer 1992), is based on the view of organizations as "information-processing systems which enact and respond to complex, dynamic, equivocal environments in pursuit of multiple, conflicting, ambiguous goals" (Van Sell, Brief and Schuler 1981:62). Role distance would sensitize occupants of boundary-spanning roles to conflicting information and environmental uncertainty. According to this view role conflict and ambiguity are the tools "by which organizations provide their members with the discretion to respond to new information and to pursue sequentially a set of conflicting out necessary organizational goals" (Weick 1979).

Role distance describes the influence of organizational characteristics, like different goals. I expect that less role distance will lead to fewer mistakes because of better execution and integration of sub-tasks. Based on literature it is also possible to formulate an alternative hypothesis about the flourishing influence of role distance on accident-proneness. In a methodological sense role distance is a much less problematic concept than 'irrationality'; there are well-known and validated instruments to measure role conflict and ambiguity (these will be discussed in paragraph five). However studies about the multiple determinants of role distance are still very rare.

3 Safety as a goal

The concepts of risk and mistakes, introduced before, refer to an orientation towards future events and to the problem of not being sure about the attainment of goals. Here goals include both organizational goals and individual goals. Individuals do not just 'copy' the goals of the organization they work in. Individual employees tend to adopt simplifying assumptions about organizational goals and the environment (Simon 1997: bounded rationality). And many organizational goals (and individual tasks to reach these goals) are loosely formulated, lacking unequivocal criteria. The goals can be very diverse and even diametrically opposed, still I do not assume that the individual goals only reflect personal interests. Organizational goals and other contingencies (the 'frame of reference') provide the individual employees with some reference points of their goals.[5] "The individual is willing to make impersonal organizational decisions because a variety of factors, or incentives, tie him to the organization–his salary, prestige, friendship, and

[5]Mascini (1999:41-58) distinguishes four different potential motives behind 'safety as a goal'. His research shows how the desire to stay healthy, or not to get an accident, is most important. This is followed by the desire not to cause an accident that harms others. At the third placed is the desire not to be hold responsible for accidents. And the least important motive is the lower operating result because of accidents.

many others" (Simon 1997:287). As a consequence these goals (priorities) can be changed within the environment by manipulation of the reference points.

The reference points are related to "the subjective propensity to take risks", an element of the risk 'thermostat' described by Adams (1995). These points are highly dependent on the reward system and the (subjectively perceived) risk. E.g. in many organizations a common assumption is that working many hours would be in the interest of both the organization and the individual employee. In 1918 Vernon published a spectacular research: an increase in work time from 60 to 72 hours was associated with two and a half times more accidents (Dwyer 1991:58). The central idea of this 'fatigue theory' is that tired workers have accidents. From a broader perspective Simon (1997: Ch.X) describes how priorities and contradictory interests (Simon: identification, loyalty), can lead to role conflict. Here, the general hypothesis is that priorities and contradictory interests produce reference points which stimulate role conflict and situations like time pressure or overtime, and cause accident-proneness.

The anthropological concept of culture often involves values, beliefs, and roles. However in safety literature the concept of 'safety culture' (Weick 1987 and HRT: 'culture of reliability') seems to be used in a very loose way, or to refer mainly to norms, attitudes, and practices (e.g. Pidgeon 1991, 1997, Bax 1992, van Vuuren 1998, Meijer 1999). After measurement the narrow meaning almost equals 'goal', or at least goal is considered to be a culture element by many. Safety as a goal involves norms that guide practices at once, and the relative importance of safety compared to other goals (e.g. whether to accept risks because of high time pressure). I prefer the concept of goal because it does not suggest an insight in the profound values of people, it does not imply that an undesirable situation cannot be changed in the short term (as culture does), and no valid instrument to measure safety culture is known[6].

[6] A petty exception is Koch (1993), who tries to 'develop and validate an assessment device' of 37 items. Especially four factors would be descriptive of a general safety culture: accountability/responsibility, adaptiveness/responsiveness, hazard awareness and maturity.

Priorities

Organizational effectiveness can be seen as a construct with a plethora of constituent concepts. While all organizational research is aimed, ultimately, at identifying effective performance and it is the fundamental dependent variable, "... no valid theories of organizational effectiveness exist in organizational behavior, and no list of criteria has ever been formulated that is either necessary or sufficient for evaluating the construct" (Cameron in: Creed, Stout and Roberts 1993:57). The constituent concepts represent only one aspect of the total construct space, one 'dimension', examples are economic efficiency, cost leadership, differentiation, power, employee well-being, safety etc.[7]

Choosing only one dimension of organizational effectiveness to study, avoids the problem of the dependent, or performance variable 'effectiveness', and formulation of a list of criteria. Priority of safety simply refers to the way safety is defended against a variety of other goals like time pressure and a limited budget (freely rendered from Groeneweg 1994). But priority of safety still asks for the identification of constraints. The contingency approach places the origins of norms (of ineffectiveness) with external

[7]Cameron suggests that the greatest source of consensus on the performance criteria could come from refocusing attention on the sources of ineffectiveness (here: an explicit focus on avoiding mistakes). People who can agree on nothing else will recognize that they share their reluctance against factors that inhibit successful organizational performance; so ineffectiveness is a non-goal. According to Cameron (in: Creed et. al.) it would also enable analysis more responsive to the practical concern for the elimination of ineffective or unreliable procedures and behaviors, and for the continuation of effective ones. Here the non-goal is one aspect of reliability: safety, it involves harmful deviations within reference points and practices.

agents. Here political power, media coverage and public sentiments play an important role in identification of the performance criteria.

The interpretation of cues about the environment, and the identification of constraints, goals and referents provide an organization with priorities. In other words, priorities find their origin in the (potential) result, e.g. economical or worst-case scenario, in its interaction with the environment. The value based reference points within the environment are, because of changing political and social forces, time and place specific. In today's Dutch society, for the organizations under study the antithesis of safety are chemical dangers so consequential that the entire organization could through failure impetuously lose the acceptance of the environment in which it operates. Because in this research the focus is on the primary process (or: transformation process) departments like marketing are part of the environment (and likely to be a main source of production pressure).

Probably the main rival, that safety has to be defended against, is productivity. In his 1996 article, Bill Richardson examines the development of modern management and portrays it as a major problem-causer in modern society, rather than a problem-solver. "Although scientific management is a vital underpinning to strategic development in a highly competitive, productivity-conscious, organizational world, its intense, single-minded and tunnel-visioned application raises the paradox of it being at one and the same time, 'saint and sinner'. Its 'saint' role is that of an economic productivity enhancing, competitive capability bestower". On the other side, Richardson focuses on the impact of 'downsizing' - an outcome of our presently extreme applications of scientific management - as a creator of a number of "crisis/catastrophe trigger points". The trigger points are born from the impact of the delayering of organizational personnel and the reduction of people employed and jobs available. Reorganization and increased work loads are factors which have featured in a number of accidents of the past decade, such as those at Tenerife, Zeebrugge, and many others.

So, safety can be described as the characteristic of an organization that performs with little or no harmful deviations in its outcomes. Priority of safety can be considered a non-goal, sought for whole organizations. The constraints and contingencies have to be

translated into organizational goals by organization participants and attention should be paid to the relative importance of each objective. Safety cannot have the highest (or sole) priority within any organization. In that case would, logically spoken, be the best solution to stop the production to avoid any risk. However within any organization safety should have a certain priority, and this has to be more or less consistent and sufficiently clear among all employees. For example, the objective within organizations should not be 'as safe as possible' but e.g. 'no overtime after dark'. After this, an obvious hypothesis is that a higher and more clear priority of safety will (because of decreased role conflict) lead to less accident-proneness.

Contradictory interests

Priority of safety is practically a functionalist concept, which assumes a unitary view of organizations; organizations treated as cooperative systems in pursuit of (more or less) common goals. Interests, on the other hand, follow from a more critical, neo-Marxian, or pluralistic perspective on organizations; organizations as a collection of factionalised groups with different goals and internal conflicts. Interests are about the (contradictory) goals of groups and individuals within an organization and the covert resistance to goals. Different employees within an organization will hold different goals (Cameron: 'different positions within the construct space'), they are often in conflict not because of confusion about organizational priorities, or uncertainty about risks, but because they have different interests.

Contradictory interests is about the different goals within an organization. Different (groups of) employees have different goals, or 'hidden agendas'. Simon (1997:214) describes this as the extent to which someone's attitudes and actions are conditioned by personal interests rather than organizational priorities, as described by the reaction: "You run your department, and I will run mine." The personal interests can be derived from identification with team, shift or department, or from private goals. Each agent within the organization is concerned with a particular problem involving risks, and has its own view of how risky activities are likely to be. One may view a longer shut-down period as an

economic loss, while for others a shorter period is seen as a threat to their safety. Interests are based on different values. “Risk and its management should be viewed as a game in which the rules must be socially negotiated within the context of a specific problem” (Kunreuther and Slovic 1996:11). This game is a process in which people advance their individual or shared interests by amassing power and using it. Political processes may either reinforce or overturn existing power structures to deal better with changing environmental conditions (Pfeffer 1981, Meyer and Starbuck 1993, Creed, Stout and Roberts 1993).

Studies identifying and evaluating conflicts showed, if more severe conflicts are taken into consideration, a correlation between the number of conflicts and the number of accidents (Leplat 1987:187). Nevertheless within (safety) literature no clear distinction is made between the influence of contradictory interests horizontally (e.g. between different departments or coworkers) and contradictory interests vertically (e.g. between employees and supervisor, or between shop floor and staff). Here the hypothesis is that in a situation with (harsh) conflicts there will be more accident-proneness. More precise: I expect contradictory interests, both horizontally and vertically, will (because of more role conflict) lead to accident-proneness.

4 Field study

The empirical part of my research is carried out within eight different organizations (A - H). These are organizations within the Dutch exploration and chemical industry and they operate around different processes related to the exploration of gas, and the production of base - and functional chemicals. They are, as a joint venture or as a full daughter, part of multinational companies. The organizations under study can be described as complex and tightly coupled[8], and know about the same degree of technology. The main chemical

[8]Because of chemical characteristics of the (raw) materials, it is not realistic to decouple different activities much further to reduce their ‘detailed interdependence’.

risks within these eight organizations are: high energy concentrations, high pressure, intoxication, poisoning, fire, and explosion. They have a comparable structure of positions, and similar departments can be distinguished: production, maintenance, and staff/technology.

A field study during a shut-down, within one of the eight organizations, consisted out of participating research and interviews. The main goal was to do observations to obtain an inward view of the production process, the course of a shut-down, the main tasks of the different functions and departments, the coordination process during toolbox and other meetings, etc. Beside this, within six of the eight organizations, more than twenty interviews were conducted with plant managers, safety officers and other key-persons. These lasted in between 90 and 120 minutes each.

Because of statistical reliability finally a questionnaire approach was chosen. Based on the analysis of accident reports, interviews, and scales derived from literature (e.g. Miller 1991) survey items were applied to the situation within the chemical industry. The measurement scales of these items were mostly five-point Likert scales. In May 1999 this survey was sent to all employees within the production, maintenance and shipping sequences within organizations A - H, and their staff. The respondents were operators, (different kind of) engineers, shippers, support staff, supervisors, etc. 436 employees cooperated within the research (equals 56% response). The response can be qualified as a relatively high one (at least for Dutch standards). And, for the chemical industry in the Netherlands, it is probably a representative cross selection of the population.

Table 1: ***Characteristics of the survey respondents***

Organization	A	B	C	D	E	F	G	H	Total
Response %	56	60	72	39	65	52	65	76	56
Response #	44	36	29	81	52	83	36	75	436
Production*	21	26	21	45	41	55	29	54	292
Maintenance	20	8	5	30	6	23	5	15	112
Other**	3	2	3	6	5	5	2	6	32
Executive and supervisory staff	15	13	12	41	15	30	13	27	166

Organization	A	B	C	D	E	F	G	H	Total
Non-supervisory staff	29	23	17	40	37	53	23	48	270

*: includes shipping department. **: includes technology department and staff
(In case of some scale-analysis N > 436 because of inclusion of organization I).

The eight organizations can be described by some simple indicators (table 1). At first sight the most startling numbers are the ratio between executive and non-supervisory staff within organization D, and the one between production and maintenance within organization A. The last ratio can be explained by the fact that the maintenance department of organization A is actually working within three different organizations (A, C and G). To preserve confidentiality, these organizations will not be described in more detail.

5 Measurement

To measure the different aspects of accident-proneness, I combined two 'subscales': (1) items about the frequency and severity of (near-) accidents within the last three years, and about the 'general' safety within an organization and (2) items about the frequency and kind of mistakes made by colleagues. (For development and validation of the measurement device see Van As 2000).

To measure role conflict and ambiguity items are used based on the conflict and ambiguity scales developed by Rizzo, House and Lirtzman (1970, also: McLaughlin 1986:494) and the identification and commitment scales developed by Van Veldhoven and Meijman (1994). In case of role conflict, 9 questions are asked about conflicts at the level of individual tasks (Likert scales, Alpha = .7949; N 450, total score: 0 - 40). E.g. 'Do you have to do your work in another way than you would like to?' and 'Often I have to do unnecessary work'. To measure role ambiguity, 12 items were included about ambiguities at the level of individual tasks (Likert point scales, Alpha = .8253; N 420,

total score: 0 - 48). E.g. ‘I know exactly what my duties are’ and ‘I know how I’ll be evaluated’.

Goal is a construct that exists out of two concepts: priorities and interests, both describing goal consensus and clarity. Priority of safety involves the relative priority of safety as an organizational goal towards other goals like production/time pressure, or a limited budget. Interests include the different goals (or: the covert resistance to goals) of individuals and groups within an organization; conflicts, or commitment and cooperation, between departments and individuals. I suggested a distinction between contradictory interests: horizontally and vertically.

To measure priority of safety, items are used partly based on the ‘incompatible goals scale’ developed by Wagenaar, Souverijn and Hudson (1993). For measurement, six questions are asked about the relative priority of safety (Likert scales, Alpha = .7388; N 414, total score: 0 - 24). E.g. ‘In our organization money is much more important than safety’ and ‘The budget for safety is much too limited’. To measure contradictory interests vertically, items are used that are partly based on a scale developed by Trommelen and Zeelenberg (1993). For measurement, only four questions are asked about the relation between employees and supervisor and between shop floor and staff (five point Likert scales, Alpha = .6988; N 426, total score: 0 - 16). E.g. ‘In general supervisors and employees get along together pretty well’ and ‘Do you have conflicts with your supervisor about the contents of your tasks?’.

To measure contradictory interests horizontally, items are used based on the ‘working with each other scale’ developed by Georgopoulos and Mann (1962). For measurement seven questions are asked about the relation between different departments and between coworkers (Likert scales, Alpha = .7196; N 382, total score: 0 - 28). E.g. ‘When there are problems, my department/team/shift (the smallest one) receives a lot of support from other departments/teams/shifts’, ‘Do the people from different departments who have to work together do their full share, so that each contributes to making the other person’s work a little easier?’ and ‘All employees are pulling in the same direction; they pursue the same goals’.

6 Analysis

The data can be analyzed at two different levels: (1) A quantitative analysis at individual level, and (2) an analysis at organizational level based on the quantitative data combined with more qualitative data. For the analysis at individual level the environment of each respondent is treated as a discrete organization. The advantage is that the organizational influences can be detected on a more detailed level. For example the influences of different departments, and factories within the same organization could be discerned at this level. The disadvantage is that this analysis does not make a clear distinction between organizational characteristics and characteristics of the respondent (e.g. a critical or even plaintive attitude towards the organization). For this reason we have to complement the analysis at individual level with a more conservative analysis at organizational level. Here we can assume the characteristics of the respondents to be the same for the eight organizations under study.

At individual level the data will be analyzed by path analysis. Path analysis is an extension of multiple regression. Its aim is to provide estimates of the magnitude and significance of hypothesized causal connections between variables. The standardized coefficient ßeta makes it possible to compare different regression coefficients. These represent the relative importance of different variables. Because there are only eight organizations under study, a reliable statistical analysis is impossible at organizational level. If possible I will try to interpret these data in a more qualitative way. First role conflict and ambiguity scores are compared to the accident-proneness score. Subsequently scores on priority of safety, contradictory interests vertically, and contradictory interests horizontally are compared to the accident-proneness and role distance scores (figure 1).